Faculty of Manufacturing Engineering

GREEN SUPPLIER MODEL FOR COMPOSITE MANUFACTURING INDUSTRY

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DECLARATION

I declare that this thesis entitled "Green Supplier Model For Composite Manufacturing Industry" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

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DEDICATION

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ABSTRACT

Environmental management has evolved to include boundary-spanning activities in the supply chain of Malaysia industry. All of these activities, whether upstream with the suppliers or downstream with the customers, relates to green supply chain management. It has become a challenge to manufacturers towards sustainable environment. Therefore, emphasis on the environmental protection by the organisational stakeholder such as stockholders, customers, government, workers and communities has become important issues in environmental management for manufacturer. Hence, it is rising recognised that a strong and important relationships exist between manufacturer and the supplier to achieve the improved result in environment protection. However, there appears to be limitations on how these two entities, 'manufacturers' and 'supplier' are integrated within an identification and development of green concept to realize a goal of better environment. The objectives of the research are to investigate the requirement of a green supplier for manufacturing composite industry, to develop a green supplier model by using Analytical Hierarchy Process (AHP) and Quality Function Deployment (QFD) tools, and to make recommendation for green supplier best practices in order to improve the performance of company towards green operation. The research consists of literature review followed by case study on four composites manufacturing companies. The second part of the research involves the development of green supplier model which developed to adapt the principles of QFD approach while AHP is used as decision making for analysis the requirement of criteria in green supplier model. There are 24 sub-green criteria, four purchasing components and 12 elements of success factor that have strong relationship between each factor that gives the better impact for the implementation of green supplier. Nevertheless, out of the 24 listed sub-green criteria, only ten of them have highest significant effect which can be divided into three main green criteria: environmental management; green competencies; and green performance. The environmental management consists of implementation of ISO 14001, employees training on environmental and government regulatory compliance. Meanwhile, environmental-friendly raw materials, recycling of materials, and green considerations in design were contributed to green competencies. For green performance; restrict and prohibit use of hazardous substances, reduce water waste disposal, remanufacturing/rebuild/reuse of product, and reduce solid waste are being selected as the critical measure. The four purchasing components consist of supplier selection and assessment, supplier performance criteria, supplier approval process and purchasing process been analysed as most important activities that influence green supplier. Besides, top management commitment, workers commitment, identification of customer needs/customer focus, and documentation of preferred suppliers and a system that been used were recognised as the highest relative importance elements for success factor. In addition, supplier practices and performance been identified as specific measures simultaneously in setting the operational strategy for business advantages and sustainable development. Green Supplier Model is able to explain and enhance the awareness of the significance of green practice in managing supplier with critical success factor that can ensure the effective implementation towards green operation.

ABSTRAK

Pengurusan alam sekitar telah berkembang untuk merangkumi aktiviti-sempadan yang melibatkan rantaian bekalan industri di Malaysia. Semua aktiviti-aktiviti ini, sama ada bermula dengan pembekal atau berakhir dengan pelanggan, mempunyai perkaitan dengan pengurusan rantaian bekalan hijau. Ia telah menjadi satu cabaran kepada pengeluar ke arah kesejahteraan alam sekitar. Penekanan terhadap perlindungan alam sekitar oleh pihak berkepentingan seperti pemegang saham, pelanggan, kerajaan, pekerja dan masyarakat telah menjadi isu penting dalam pengurusan alam sekitar bagi pengeluar. Ia semakin disedari bahawa hubungan yang kukuh dan penting wujud di antara pengeluar dan pembekal bagi mencapai keputusan yang lebih baik dalam perlindungan alam sekitar. Walau bagaimanapun, ia adalah terhad kepada bagaimana „pengeluar" dan „pembekal-dua entiti" disepadukan dalam mengenal pasti dan membangunkan konsep hijau untuk realisasikan matlamat alam sekitar yang lebih baik. Objektif kajian ini adalah untuk menyiasat keperluan pembekal hijau bagi industri pembuatan komposit, untuk membangunkan satu model pembekal hijau dengan menggunakan kaedah "Analytical Hierarchy Process (AHP)"dan "Quality Function Deployment (QFD)", dan untuk mencadangkan amalan terbaik bagi pembekal hijau bagi meningkatkan prestasi syarikat ke arah operasi hijau. Kajian ini melibatkan kajian lepas dan diikuti oleh kajian kes di empat buah syarikat pembuatan komposit. Bahagian kedua kajian ini melibatkan pembangunan model pembekal hijau yang dibangunkan bagi menyesuaikan prinsip-prinsip pendekatan QFD manakala AHP digunakan sebagai menandakan keputusan untuk menganalisis keperluan kriteria dalam model pembekal hijau. Terdapat 24 sub-kriteria hijau, empat komponen pembelian dan 12 elemen faktor kejayaan yang mempunyai hubungan kuat antara setiap faktor bagi memberikan kesan yang lebih baik untuk keberkesanan pelaksanaan pembekal hijau. Namun begitu, daripada 24 sub-kriteria hijau yang disenaraikan , hanya sepuluh daripada mereka mempunyai kesan yang tertinggi yang boleh dibahagikan kepada tiga kriteria hijau utama: pengurusan alam sekitar; kecekapan hijau; dan prestasi hijau. Pengurusan alam sekitar terdiri daripada pelaksanaan ISO 14001, latihan kakitangan mengenai pematuhan undang-undang kerajaan dan alam sekitar. Sementara itu, bahan-bahan mentah yang mesra alam, bahan-bahan kitar semula, dan pertimbangan hijau dalam reka bentuk telah menyumbang kepada kecekapan hijau. Untuk prestasi hijau; menyekat dan melarang penggunaan bahan berbahaya, mengurangkan pelupusan sisa air, pembuatan semula / membina semula / penggunaan semula produk, dan mengurangkan sisa pepejal telah dipilih sebagai langkah yang kritikal. Empat komponen pembelian terdiri daripada pemilihan pembekal dan penilaian, kriteria prestasi pembekal, proses kelulusan pembekal dan proses pembelian telah dianalisis sebagai aktiviti yang paling penting yang mempengaruhi pembekal hijau. Selain itu, komitmen pengurusan atasan, komitmen pekerja, mengenal pasti keperluan pelanggan / keutamaan pelanggan, dan dokumentasi pembekal pilihan dan sistem yang telah digunakan telah diiktiraf sebagai kepentingan relatif tertinggi bagi unsur-unsur faktor kejayaan. Di samping itu, amalan dan prestasi pembekal dikenal pasti sebagai langkah-langkah yang khusus sekaligus dalam menetapkan strategi operasi bagi kelebihan perniagaan dan pembangunan mampan. Model pembekal hijau mampu untuk menjelaskan dan meningkatkan kesedaran tentang kepentingan amalan hijau dalam pengurusan pembekal dengan faktor kejayaan kritikal yang boleh memastikan pelaksanaan yang berkesan ke arah operasi yang hijau.

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LIST OF ABBREVIATIONS

AHP	-	Analytical Hierarchy Process
AI	-	Artificial Intelligence
ANP	-	Analytic Network Process
ASL	-	Approved Supplier List
AVL	-	Approved Vendor List
CCA	-	Customer Competitive Assessment
CIR	-	Customer Important Rating
DEA	-	Data Envelopment Analysis
DEA	-	Data Envelopment Analysis
DO	-	Delivery Order
ECC	-	Engineering CAD Centre
EMS	-	Environment Management System
FRP	-	Fibre Reinforced Polymer
GC	-	Green Competency
GDP	-	Gross Domestic Product
GDR	-	Goods Discrepancy Report
GP	-	Green Performance
GRF	-	Good Received Form
GRN	-	Good Received Note
GSCM	-	Green Supply Chain Management
GSM	-	Green Supply Model

HOQ	-	House of Quality
IBS	-	Industrial Business solution
IT	-	Information Technology
JV	-	Joint Venture
KPIs	-	Key Performance Indicator
KPIs	-	Key Performance Indicators
LAR	-	Lot Acceptance Rate
LAR	-	Lot Acceptance Rate
MPMgt	-	Material Purchasing Manager
NCR	-	Non Conforming Report
NPD	-	New Product Development
PEF	-	Periodical Evaluation Form
PO	-	Purchase Order
PR	-	Purchase Requisition
PRC	-	Percentage of Part Rejection Claim from Production
Pre-Q	-	Pre-Qualification
QC	-	Quality Control
QFD	-	Quality Function Deployment
QMS	-	Quality Management Sheet
RA	-	Respondent A
RB	-	Respondent B
R&D	-	Research and Development
RPN	-	Request Purchase Note
SC	-	Sub- Criteria
SCAR	-	Supplier Corrective Action Request
SCM	-	Supply Chain Management
SCOR	-	Supply Chain Operational Reference

SDP	-	Supplier Development Program
SDR	-	Service Discrepancy Report
SF	-	Success Factor
SPA	-	Supplier Performance Assessment
SPC	-	Statistical Process Control
SPD	-	Supplier Development Program
SPM	-	Supplier Performance Measure
SPM	-	Supplier Performance Measure
SQA	-	Supplier Quality Assurance
TCA	-	Technical Competitive Assessment
TCF	-	Technical Correlation Roof
TCR	-	Timely Communication and Responsiveness
TQM	-	Total Quality Management

LIST OF SYMBOLS

AW_i	-	Value of matrix times weightage
CI	-	Consistency Index
n	-	No. of matrix
RI	-	Random Index
T_i	-	Total of *i* Matrix
W_i	-	Weightage of Eigenvector
λ_{max}	-	Eigenvalue
O	-	9
□	-	3
Δ	-	1
Tj	-	Total of j matrix (j row)

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Environmental protection has increasingly become important to business research and practice, over the past decades as a result of rapid depletion of natural resources and high pollution level. Thus, to protect the environment both proactive and reactive methods have been implemented (Lee et al., 2009). The program such as Green Supply Chain Management (GSCM) has been practiced in order to conscious environmental protection (Sarkis, 1998). The purpose of GSCM is to reduce environmental pollution from upstream to downstream starting from raw materials into end user customers (Kuo et al., 2010).

The fundamental supply chain of manufacturing companies is the requirement to handle the flow of raw material starting from supplier through the value adding processes and ended with distribution channels to the customer. It is involved with planning, controlling and coordinating materials, parts and finished goods from suppliers to the customers, where this process is a connected series of activities in supply chain. The approach of GSCM has been applied to ensure the control flow of materials from suppliers emphasised on the awareness of environmental issues.

The factors such as leak and diminishing of raw material resources, environmental pollution increase and overflowing waste sites have driven the rising of GSCM awareness to manufacturer (Srivastava, 2007). In GSCM, supplier has become an important part in order to manage the good environmental protection. Thus, manufacturer must take an action to develop a Green Supplier Model (GSM). However, to choose an appropriate GSM becomes a crucial issue (Kuo et al., 2010). Every factor and criteria must be taken seriously in development of GSM to achieve the effectiveness.

Green supplier is defined as a vendor that provides and supply materials or products by monitoring and controlling their environmental performance (Hsu and Hu, 2009). Purchasing play an important role in development of GSM because of strong relevance between purchasing (buyer) and supplier (Humphreys et al., 2004; Liu et al., 2012) . As known that the Purchasing task is to buy a goods and service (supplier) for delivers maximum value to the company (Monczka et al. 2009; Lee at al. 2009). For successful implementation of green supplier in company, purchasing must be the main part of it. In order to create a GSM, the manufacturer must define the criteria of the supplier in line with the company objectives and goals. Four components of purchasing in GSM have been introduce to achieve the green supplier concept, which are supplier assessment and selection (Handfield et al., 2002; Bai and Sarkis, 2010), supplier performance (Gunasekaran et al., 2001; Hervani et al., 2005), Approved Supplier List (ASL) based on environmental criteria (Cousins et al., 2004) and purchasing process (Maignan et al., 2002).

Supplier assessment and selection have become a popular method to identify the green supplier model. Starting from 1960s early research from first publication can be traced back, and the researchers such as Weber et al. (1991) and Ghodsypour and O'Brien (1998) did a comprehensive review on the past research about supplier selection that

related to environmental protection (Lee et al., 2009). Supplier assessment has been defined as a tool to evaluate the early process of selecting the supplier based on company objectives and goals. Many techniques have been applied to determine the supplier assessment such as categorical method (Keskin et al., 2010), the weighted-point method (Dulmin and Mininno, 2003), and the matrix method (Xia and Wu, 2007).

The selection of right supplier in conducting the environmental resource can increase the efficiency of the environmental protection (Choy and Lee, 2002). The supplier performance measurement has been introduced in order to evaluate the overall performance of the selected supplier. Thus, to evaluate the supplier performance, the company must identify the criteria for the evaluation that in line with company objective and the individual strategic business unit‘s characteristics (Hervani et al., 2005). The set of criteria for measuring the supplier performance include supplier ability to supply high quality and responsibly sourced raw material, cost of raw material, delivery performance, service, supply turnover and inventory performance (Mahmood et al., 2011).

The approach of ASL is to identify and guides the purchasing department in purchase activities. It contain the list of approved supplier that has been determines and approved by higher authorities based on supplier assessment and supplier performance measure (Gencer and Gürpinar, 2007). In addition, the ASL must be always updated to ensure the effectiveness of this list and minimising the risk in sourcing and buying (Roy, 2003). The element of green supplier concept has been implemented to ASL system to ensure company can sustain the use of raw material resource effectively. Supplier approved procedures must be complied with by any department in the company, especially the purchasing department to ensure the company benefits and avoid loss in buying.

The purchasing section plays an important role as the starting point in this physical movement of material flow. The consideration on the environmental issues in purchasing process making it becomes more complicated process (Lee et al., 2009; Govindan et al., 2013). This is because green purchasing is not only considering the traditional criteria such as supplier‘s cost, quality, service and delivery but also must consider the element of supplier‘s environmental responsibility. The objectives of managing the purchasing process are to conduct the flow of purchase goods and service starting from identifying needs, locating and selecting suppliers, negotiating terms, following up to ensure supplier performance and updating ASL system.

In this research, GSM was developed based on these four components of purchasing stated; supplier assessment and selection, supplier performance measure, ASL, and purchasing process. Four composites manufacturing industries based in Malaysia were selected to explore these four components of purchasing for case study and collecting the data. The analysis of the data was used to define the best model for green supplier concept in Malaysia.

1.2 Problem Statement

Nowadays, Malaysia has made a progress in environmental management by implementing laws and strategies that focus on sustainable development and green issues such as _Program MyHIJAU‘ to encourage industrial manufacturers and suppliers in offering green goods and services that are more competitive and environmental friendly (MTHPI, 2012). In spite of this notion, most composites manufacturers in Malaysia still do not recognise the need to apply the green concept in their supplier‘s selection (Oly Ndubisi et al., 2005). Most of them still use the basic of selecting the supplier base on general requirement such as quality, price, and service.